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ELF Rotating Magnetic Fields: Prenatal Exposure and Adult Behavior

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With 1 Figure

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Summary

In three separate experiments, adult male rats that had been exposed continuously during their prenatal development to a 0.5 Hz, 3 to 30 gauss rotating magnetic field (RMF), emitted significantly ($p < 0.01$) fewer lever presses in a free operant avoidance situation than rats that had been prenatally exposed to control conditions. This difference was apparently due, in large part, to the RMF-exposed rats' relatively low response rate within response bursts following a shock. However, RMF-exposed rats did not differ significantly from control rats in the number of shocks received.

Zusammenfassung

Verhaltensweise erwachsener Versuchstiere nach vorgeburtlicher Aussetzung in ELF-rotierenden Magnetfeldern

In drei unabhängigen Untersuchungen gaben voll entwickelte männliche Ratten, welche während ihrer vorgeburtlichen Entwicklung einem 0.5 Hz, 3 bis 30 Gauss rotierenden magnetischen Feld (RMF) ununterbrochen ausgesetzt waren, bedeutend weniger ($p < 0.01$) Tastendrücke in einer freien operanten Vermeidungssituation ab als Ratten, welche vorgeburtlich Kontrollkonditionen ausgesetzt waren. Dieser Unterschied war offensichtlich zu einem großen Teil darauf zurückzuführen, daß die dem RMF ausgesetzten Ratten eine verhältnismäßig niedrige Ansprechschwelle innerhalb der den Elektroschocks folgenden Responsestößen von sich gaben. Es bestand jedoch kein signifikanter Unterschied in der Zahl der Elektroschocks, die den dem RMF ausgesetzten Ratten und Kontrollratten gegeben wurde.

Résumé

Champs magnétiques ELF:
Exposition prénatale et conduite des animaux developpeés

En trois expériences indepéndantes, les rats mâles adultes qui avaient été exposés sans interruption pendant leur développement prénatal à 0,5 Hz et 3 à 30 gauss d'un champ tournant (CT), ont émis significativement ($p < 0.01$) moins de pressions à levier dans une situation libre opérante à éviter que les rats qui avaient été prénativement exposés aux conditions contrôlées. Cette différence était apparemment causée, en grande partie, par la relativement basse vitesse de résponse des rats exposés à CT, pendant les éclatements des résponses suivant un choc. Cependant les rats exposés à CT n'ont pas différé significativement des rats de contrôle dans le nombre de chocs reçus.

1. Introduction

Especially low frequency (ELF) electromagnetic fields (0.1 Hz to 50 Hz), similar to those which occur in nature, have been demonstrated to have immediate effects upon behavior. KONIG [5] and FRIEDMAN, et al. [4] have reported changes in reaction time while WEVER [11], ALTMANN [1], and DOWSE and PALMER [3] have reported changes in locomotor activity in the presence of ELF electromagnetic fields. Recently, PERSINGER [6] reported that rats that had been exposed continually during their *prenatal* development (removed at birth) to a 0.5 Hz, 3 to 30 gauss rotating magnetic field (RMF), emitted a significant decrease in locomotor activity but an increase in defecation when tested at 21 to 25 days of age. In order to determine if other modifications of behavior due to prenatal exposure to the RMF could be detected in adult organisms, it was decided to test adult rats in a more controlled operant paradigm.

The SIDMAN [7] or free operant avoidance procedure was selected since it is a standard operation in behavior laboratories and has been used successfully in physiological research by SIDMAN, et al. [8] to measure the effects of pituitary-adrenal activity and by Verhave [10] to measure the effects of metamphetamine. In the free operant avoidance procedure, which involves no extereoceptive stimulus, each avoidance response postpones an electrical shock for a predetermined interval of time (*R-S* interval). Failure to respond results in the delivery of a series of shocks separated in time by a fixed interval (*S-S* interval). Studies have found that rate of avoidance responding is related in an orderly manner to both *R-S* and *S-S* intervals, as well as shock intensity.

2. Method

In three experiments, 24, 70 to 80 day old male Wistar strain albino rats which had been tested in an open field at 21 to 25 days of age, were used as subjects. Twelve of the rats had been randomly selected from 10 litters that had been exposed prenatally to a RMF [6], while the remaining 12 rats were randomly selected from 10 litters that had been prenatally exposed to control conditions. Four RMF-exposed rats and four control rats were used in each experiment.

Two commercial operant conditioning chambers, with one lever mounted against one wall, were used in Experiments I and II while only one chamber was used in Experiment III. A constant power stimulator delivered shock via a scrambling device to the grid floor and sides of the chamber. Each chamber was housed in a sound-insulated box which was located in a sound-insulated man-sized cubicle. The automatic programming equipment and recording apparatus were placed outside the cubicle.

At 30 days of age, the males which were to be used as subjects were removed from their litter mates and placed in 43 cm by 24 cm by 18 cm wire cages. Four rats of the same condition were housed in each cage until and during the test period. Since previous data had suggested a relationship between body weight and response rate, RMF-exposed and control rats were paired for weight as closely as possible. Purina food blocks and water were available ad libitum in the home cages.

The avoidance schedule was programmed so that the rats received a 2.2 mA, 0.5 sec shock every 5 sec (the *S-S* interval) unless a lever press occurred, in which case the shock was postponed for 20 sec (the *R-S* interval). Each session lasted 3 hrs. In all three experiments, the total number of lever presses emitted and shocks received was recorded for each session. These measures were also taken on a cumulative recorder.

A total of 15 sessions was completed. The time between successive sessions was 24 hrs, except between the first two sessions, during which 48 hrs elapsed. In Experiments I and II (two chambers), RMF-exposed and control rats, paired for weight before the experiment, were run at the same time while in Experiment III (one chamber), pairs were run in a RMF-exposed-control, etc. order. To control for chamber differences (Experiments I and II), the number of animals in a given box for each group was equalized.

3. Results

For analysis, the fifteen sessions of each rat were divided into five blocks of three sessions each. The rat's average number of shocks received or responses emitted in the three sessions was the value used to obtain the mean for each group and block. The 12 RMF-exposed rats averaged 3.2, 2.0, 1.6, 1.3, and 1.1 shocks per min over the five blocks while the control rats averaged 3.5, 2.0, 1.6, 1.3, and 1.0 shocks per min. This difference was not significant. However, the RMF-exposed rats averaged 6.9, 7.6, 7.9, 8.0, and 7.7 lever presses per min while the control animals averaged 7.3, 9.9, 11.1, 11.6, and 11.2 lever presses per min. The means and standard deviations (SDs) for each block and group of each experiment are presented in Table 1.

Table. 1. *Average Responses per Minute for Magnetic and Control Groups*

	Magnetics [$n=4$]					[Controls $n=4$]				
	Blocks					Blocks				
	1	2	3	4	5	1	2	3	4	5
Experiment I										
M	6.3	7.0	7.8	7.7	7.3	6.3	9.6	10.2	10.7	11.1
SD	0.9	0.8	2.4	2.8	1.9	1.8	2.6	1.6	2.6	2.7
Experiment II										
M	4.6	5.6	6.3	6.3	6.0	5.8	9.8	10.3	9.8	9.5
SD	0.4	2.0	1.2	1.0	0.9	1.5	1.5	3.6	3.1	3.0
Experiment III										
M	9.7	10.4	9.6	10.1	9.8	9.6	10.2	12.9	14.3	13.0
SD	1.4	2.3	1.3	2.6	2.7	1.7	1.8	0.5	2.4	1.5

An analysis of variance, which is shown in Table 2, found the difference between treatments to be significant beyond the .01 level ($F = 11.38$). Significant differences were also found between experiments ($F = 7.67$), blocks ($F = 9.45$), and the interaction: treatment by blocks ($F = 3.46$; $p < .05$). The block significance was due to the increase of average number of responses over blocks for both groups. The interaction significance was due to the RMF-exposed rats maintaining a more constant response rate than the controls. It was also noticed that in 11 of the 12 RMF-exposed-control pairs, the RMF-exposed rats emitted fewer responses.

The largest portion of the response decrement in the RMF-exposed animals occurred within the first few seconds following a shock. Control rats emitted a rapid post shock responding ("bursting")

Table 2
Analysis of Variance for Responses per Minute for Magnetic and Control Rats

Source	*df*	*MS*	*F*
Treatment (*T*)	1	200.99	11.38**
Experiments (*E*)	2	135.41	7.67**
T·*E*	2	4.07	0.23
Error (*a*)	18	17.65	—
Blocks (*B*)	4	30.23	9.45**
T·*B*	4	11.06	3.46*
B·*E*	8	1.48	0.46
B·*T*·*E*	8	2,31	0.72
Error (*b*)	72	3.20	—

* $p < .05$
** $p < .01$

while the RMF-exposed rats did not. An example of this difference in post shock responding is presented in Fig. 1 where the cumulative response graphs for one RMF-exposed (BM-2) and one control

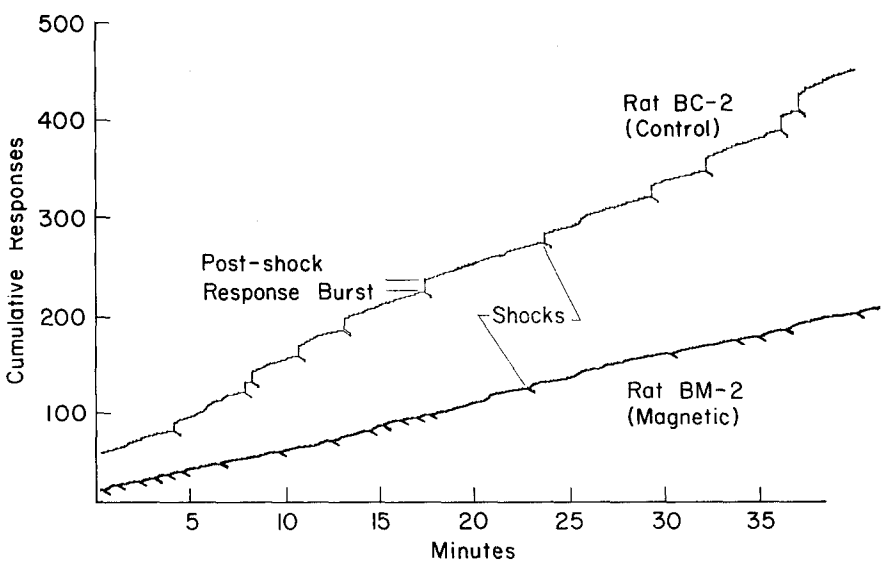

Fig. 1. Cumulative response graphs over minutes for control rat BC-2 and magnetic rat BM-2, indicating the presence or absence of „response bursts"

(BC-2) rat, experimentally paired for weight, are presented. It can be seen that the steep segments ("bursts") following slashes (shocks) are absent in the RMF-exposed rat.

4. Discussion

The data show that although the RMF-exposed rats and control rats acquired the free operant avoidance task equally well, as defined by the non significant difference between average number of shocks received, the RMF-exposed rats did emit fewer lever presses than the controls. The observed decrement in responses emitted was due, in large part, to the absence of post shock response bursts in the RMF-exposed animals. The reliability of this effect is indicated by the similarity of magnitude and direction of the differences in the three experiments. In addition, since BOREN [2] and SIDMAN [9] have reported that post shock response bursts are a characteristic behavior of rats in a free operant avoidance situation, it can be concluded that the observed response difference between RFM-exposed and control groups was not due to a peculiarity of the control rats in this study.

There are two important implications that can be drawn from the three experiments. First, although the field intensities used were of slightly greater intensity than those which occur in nature, the data suggest that prenatal exposure to natural ELF electromagnetic fields could produce significant behavioral consequences in adult organisms. Second, the use of operant techniques in environmental *behavioral* biophysics can clearly show the behavioral modifications that are a consequence of various environmental physical effectors.

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